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The Impact of Semantic Relatedness on Associative Memory in Aging Depending on the Semantic Relationships between the Memoranda

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ABSTRACT

Background: Aging is characterized by a decline in associative memory. However, under some conditions, such as in the presence of semantic relatedness within the association, the age-related associative decline can be attenuated. In this study, we evaluated whether the nature of the semantic relationship between the memoranda (taxonomic versus thematic) could modulate the impact of semantic relatedness on older adults' associative memory.

Methods: We assessed 40 young adults and 40 older adults' associative memory for associations that were either taxonomically-related, thematically-related, or unrelated.

Results: While the main results showed age-related differences in all associative memory tasks without attenuation by semantic relatedness, the results after excluding 4 outlier older participants suggest that older adults' associative memory performance did not differ from that of young adults for thematically-related pairs, while there was an age-related difference in associative memory for taxonomically-related pairs as well as for unrelated pairs.

Discussion: This could suggest that the nature of the semantic relationship between the memoranda can modulate the impact of semantic relatedness on older adults' associative memory performance, although the reason why this is not the case for all older participants still needs to be understood.

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Introduction

Aging is characterized by a decline in episodic memory that is thought to be due at least partly to an associative memory deficit (Naveh-Benjamin, 2000). Indeed, older adults display impaired memory for associations in the face of relatively preserved memory for single items (see Old & Naveh-Benjamin, 2008 for a meta-analysis). Relatedly, the age-related episodic decline is characterized by impairments in recollection – the recognition of an item accompanied by the retrieval of qualitative information about its specific study episode -, necessary for associative recognition memory. In contrast, familiarity – the recognition of information devoid of contextual detail regarding its encoding episode – is preserved in healthy aging (for reviews, see Koen & Yonelinas, 2014; Yonelinas, Aly, Wang, & Koen, 2010).

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Contrary to episodic memory, semantic memory, i.e., our acontextual knowledge about the world, is relatively preserved in healthy aging (e.g., Park, 2000) so that older adults might increasingly rely on semantic over episodic information (Ofen & Shing, 2013). This relative preservation of semantic memory in aging has thus been explored as a way to improve episodic memory through semantic memory support (for a review, see Umanath & Marsh, 2014). Doing so, studies have shown that associative recognition memory could be improved in healthy aging in the presence of prior knowledge linking the to-be-remembered information, using a wide range of materials including pre-existing compound words (Ahmad, Fernandes, & Hockley, 2015; Zheng, Li, Xiao, Broster, & Jiang, 2015), semantic relationships (Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Patterson, Light, Van Ocker, & Olfman, 2009), congruency (Mohanty, Naveh-Benjamin, & Ratneshwar, 2016; Peterson, Schmidt, & Naveh-Benjamin, 2017) and linguistic structure (Smyth & Naveh-Benjamin, 2018), even though recent evidence have pointed out that this was true under specific conditions only, for instance when a decrease in semantic support occurred between encoding and retrieval (Delhaye, Folville, & Bastin, 2019). Moreover, the presence of prior knowledge within to-be-learnt associations was shown to enhance the contribution of familiarity to associative recognition in young adults (e.g., Greve, van Rossum, & Donaldson, 2007; Zheng et al., 2015) as well as in older adults (Ahmad et al., 2015; Delhaye & Bastin, 2018; Zheng et al., 2015).

Interestingly, one study showed that the contribution of recollection and familiarity to associative recognition in the presence of prior knowledge was modulated by the nature of semantic relationships between the paired associates (Kriukova, Bridger, & Mecklinger, 2013). This study showed that associative recognition of thematic relationships could be supported by familiarity alone, while associative recognition of taxonomic relationships was supported by both recollection and familiarity. Thematic relationships are organized on the basis of the items' cooccurence or complementarity in a given context or scenario. They can be functional (e.g., bread-knife), temporal (e.g., coffee-morning), spatial (e.g., ceiling-lamp), containment (e.g., milk-jar) or causal (e.g., joke-laughter) (Kriukova et al., 2013). Conversely, taxonomic relationships (e.g., lion-tiger) are organized according to items' conceptual or perceptual similarity since the defining characteristic of categorical relations is their intrinsic feature similarity. Indeed, categorically-related concepts are typically characterized by high semantic feature overlap (for reviews, see Estes & Jones, 2009; Mirman, Landrigan, & Britt, 2017). Interestingly, some authors suggest that the first form of semantic memory organization to decline in aging is the taxonomic organization, with the thematic organization being preserved longer during the course of aging (Belacchi & Artuso, 2018).

To date, the impact of thematic relationships compared with taxonomic relationships on older adults' associative memory has never been tested. Given that recognition of thematic associations can be supported by familiarity alone contrary to taxonomic associations, and given that older adults present with a decline in recollection in the face of preserved familiarity, we hypothesize that older adults should benefit more from thematic than taxonomic relationships to improve their associative memory. Besides, because the recognition of taxonomic pairs involves familiarity to a greater extent than the recognition of unrelated pairs, older adults' performance should still be improved for taxonomic relationships compared with unrelated associations. We tested this hypothesis in the current study by manipulating the type of relation within the to-be-learnt associations.

Methods

Participants

The number of participants recruited in each group was determined by power analyses using G*Power software v3 (Faul, Erdfelder, Lang, & Buchner, 2007) for a 0.95 power, based on previous studies' effect sizes with similar design (Delhaye et al., 2019; Naveh-Benjamin et al., 2003). Fourty young (21 women) and 40 older adults (17 women) took part in the experiment. Young adults had a mean age of 24.95 years (standard deviation (SD) = 3.00) and older adults had a mean age of 67.75 years (SD = 4.25). Groups were matched in terms of education (young: mean = 15.68 years, SD = 1.99; older: mean = 15.18, SD = 3.54, W = 681.00, p = .25). All participants were recruited from the local community, were fluent French speakers and had normal or corrected-to-normal vision and hearing. All participants reported having no history of neurological or psychiatric disorder, and for older adults, they did not show any sign of global cognitive decline, as assessed by the Montreal Cognitive Assessment according to the 23 cutoff suggested by a recent meta-analysis (Carson, Leach, & Murphy, 2018) (MoCA, mean = 26.8, SD = 1.88, range = 23–29). All participants signed an informed consent form before taking part in the study, which was approved by the Ethics Committee of the Faculty of Psychology of the University of Liege.

Materials

288 words from 26 categories (13 livings and 13 non-living categories; e.g. animals, fruits, vegetables, vehicles, beverages, see Bueno & Megherbi, 2009, for further examples) were selected and organized in pairs that were unrelated, taxonomically-related and thematically-related. These word pairs were built using the same materials, but each word pair was displayed in only one of its configurations at encoding, and in only one (the same or a recombined configuration) at retrieval. This allowed us to build fourteen versions of the task in order to fully counterbalance the materials across conditions and participants. The associations came from a discrete association task that we ran as pilot study, where participants were asked to produce one taxonomic and one thematic associate for each of 208 target words (N = 480, mean age = 26.2 years; SD = 11.24; range = 16–72). We obtained a mean of 114.45 productions by target word (SD = 6.98; range: 71–130). Table 1 illustrates the study materials and design.

Procedure

Participants completed the task individually on a laptop computer using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). At the beginning of the study phase, participants

Table 1. Example of the study design for thematically-related, taxonomically-related and unrelated pairs at encoding and retrieval.

	Encoding			Retrieval		
Target word	Thematic associate	Taxonomic associate	Unrelated associate	Thematic recombined	Taxonomic recombined	Unrelated recombined
rabbit	hole	hare	stool	cheese	rat	closet
mouse	cheese	rat	closet	hole	hare	stool
pear	pie	apple	neck	cake	plum	foot
cherry	cake	plum	foot	pie	apple	neck
truck	road	bus	thistle	engine	motorbike	poppy
car	engine	motorbike	poppy	road	bus	thistle

were instructed to study the associations between the words. Ninety-six pairs were encoded at a rate of 4 seconds each, with a 500-ms blank screen and a 500-ms fixation cross between trials. Thirty-two pairs were presented in their taxonomic relationship configuration, 32 pairs were presented in their thematic relationship configuration and 32 pairs were presented in their unrelated configuration. The order of presentation of the study pairs was randomized. A 5-minute distracting phase filled with mental calculations followed the encoding phase. Subsequently, participants took part in an associative recognition test, in which 144 pairs were presented: 16 of the pairs that were taxonomically-related at encoding were presented in the same configuration as during encoding; the remaining 16 studied taxonomically-related pairs were recombined with another word from the same category, and there were 16 new categorically-related pairs; 16 of the pairs that were thematically-related at encoding were presented in the same configuration as during encoding; the remaining 16 studied thematically-related pairs were recombined with another word from the same condition, and there were 16 new thematically-related pairs. Finally, 16 of the pairs that were unrelated at encoding were presented in the same configuration as during encoding; 16 of the studied unrelated pairs were recombined with another unrelated word, and there were 16 new unrelated pairs. For each pair presented, participants had to decide whether it was intact, recombined or new, responding with the key 1, 2 or 3, respectively. For both encoding and retrieval, pairs from the different conditions were randomly intermixed. We divided the whole encoding-retrieval session into two parts to avoid fatigue effects due to the length of the list. The order of presentation of these two parts was counterbalanced across participants.

Statistical Analyses

We performed mixed repeated measures ANOVAs with group (young, older) as between-subjects factor and type of relationship (taxonomic, thematic, unrelated) as within-subjects factor on hit rates (i.e., correct recognition of intact pairs), false alarm (FA) rates to recombined pairs, FA rates to new pairs, as well as on an index of associative discrimination performance computed by subtracting proportion of FAs to recombined pairs from proportion hits to old pairs and on an index of pair memory performance (i.e., index reflecting memory for the pair based either on retrieval of the association between the words or simply on the feeling that the two words comprised in the association are more familiar than those in new pairs, Gallo, Sullivan, Daffner, Schacter, & Budson, 2004) using the difference between proportion of hits to old pairs and proportion of FAs to new pairs. Post-hoc tests on main effects were conducted using Bonferroni comparison tests. We explored interactions using independent sample t-tests or, in case of violation of the equal variance assumption, Mann-Whitney tests. The alpha level was set at .05. Additionally, we implemented JZS Bayes factor repeated measures ANOVAs with default prior scales comparing null and alternate hypotheses on the associative discrimination index of performance.

Results

Because Mauchly's test of sphericity on the hit rates indicated that the assumption of sphericity was violated (Mauchly's $W = 0.87$, $p < .01$), the Greenhouse-Geisser sphericity correction was applied on the 2 (group: young, older) x 3 (relationship: taxonomic, thematic, unrelated) repeated measures ANOVA on the hit rates. Results indicated

a main effect of type of relationship, F(1.77,138.38) = 48.83, $p < .001$, $\eta^2_p = .38$, with lower hit rates for unrelated pairs compared with taxonomically- and thematically-related pairs (Bonferroni, $p < .001$), while there was no difference between taxonomically-related and thematically-related pairs (Bonferroni, $p = .99$). There was no difference in hit rates between groups, F(1,78) = 1.86, $p = .18$, $\eta^2_p = .02$, and no significant interaction between group and type of relationship, F(1.77,138.38) = 0.08, $p = .91$, $\eta^2_p = .01$.

After checking for sphericity (Mauchly's W = .94, $p = .08$), the repeated measures ANOVA on the FA rates to recombined pairs revealed a main effect of the type of relationship (F(2,156) = 30.32, $p < .001$, $\eta^2_p = .28$), with greater false alarm rates for unrelated pairs than taxonomically-related pairs (Bonferroni, $p < .05$), and greater false alarm rates for taxonomically- than thematically-related pairs (Bonferroni, $p < .001$). There was also a main effect of group, F(1,78) = 38.18, $p < .001$, $\eta^2_p = .33$, with greater FA rates in older adults. The group x type of relationship interaction was also significant, F(2,156) = 3.80, $p < .05$, $\eta^2_p = .05$, indicating that, while older adults had significantly greater FA rates than young adults for all types of recombined pairs (unrelated pairs: t(78) = 4.77, $p < .001$, Cohen's $d = 1.07$, 95% CI [0.11, 0.26]; taxonomically-related: t(78) = 5.04, $p < .001$, Cohen's $d = 1.13$, 95% CI [0.11, 0.25]; thematically-related pairs: t(78) = 3.07, $p < .01$, Cohen's $d = 0.69$, 95% CI [0.03, 0.14][1]), the effect size was the smallest for thematically-related pairs.

The Greenhouse-Geisser sphericity correction was applied to the FA rates to new pairs (Mauchly's W = 0.86, $p < .01$) in a 2 (group: young, older) x 3 (relationship: taxonomic, thematic, unrelated) repeated measures ANOVA. Results indicated a main effect of type of relationship, F(1.76,137.41) = 9.98, $p < .001$, $\eta^2_p = .11$, with lower FA rates for unrelated (Bonferroni, $p < .01$) than for taxonomically- and thematically-related pairs, while there was no FA rates difference between taxonomically-related and thematically-related pairs (Bonferroni, $p < .26$). There was no main effect of group, F(1,78) = 3.99, $p = .049$, $\eta^2_p = .05$, and no significant interaction between group and type of relationship, F(1.76,137.41) = 2.16, $p = .12$, $\eta^2_p = .03$.

After correction for sphericity assumption violation, (Mauchly's W = .92, $p = .04$), the repeated measures ANOVA on the index of associative discrimination performance (see Figure 1), indicated a main effect of type of relationship, F(1.85,144.71) = 92.71, $p < .001$, $\eta^2_p = .54$, with better performance for thematically-related than taxonomically-related pairs (Bonferroni, $p < .001$) and better performance for taxonomically-related than unrelated pairs (Bonferroni, $p < .001$). There was also a main effect of group, F(1,78) = 8.13, $p < .01$, $\eta^2_p = .09$, but no interaction between group and type of relationship, F(1.85,144.71) = 2.38, $p = .10$, $\eta^2_p = .03$. The absence of interaction was supported by further Bayesian analysis comparing null and alternate hypotheses in a model that includes the interaction between type of relatedness and age group. Main effects of type of relatedness and age group were apparent in all models (that is, assumed to be nonzero) and were therefore treated as nuisance factors. This analysis revealed that the null model was preferred to the alternative model by a Bayes factor of 1.76, thereby providing evidence against the hypothesis that age-related differences would vary depending on the type of relatedness at encoding.

However, when checking the distribution plots of the data, we noted a subgroup of 4 outlier older participants in the thematic condition only (their performance being lower than > 2 SD of the median of their group; see Figure 1). We thus performed the same analyses on the hits-FA rates toward recombined pairs, as previously described, but this time, we excluded these 4 outlier participants. After correction for sphericity assumption

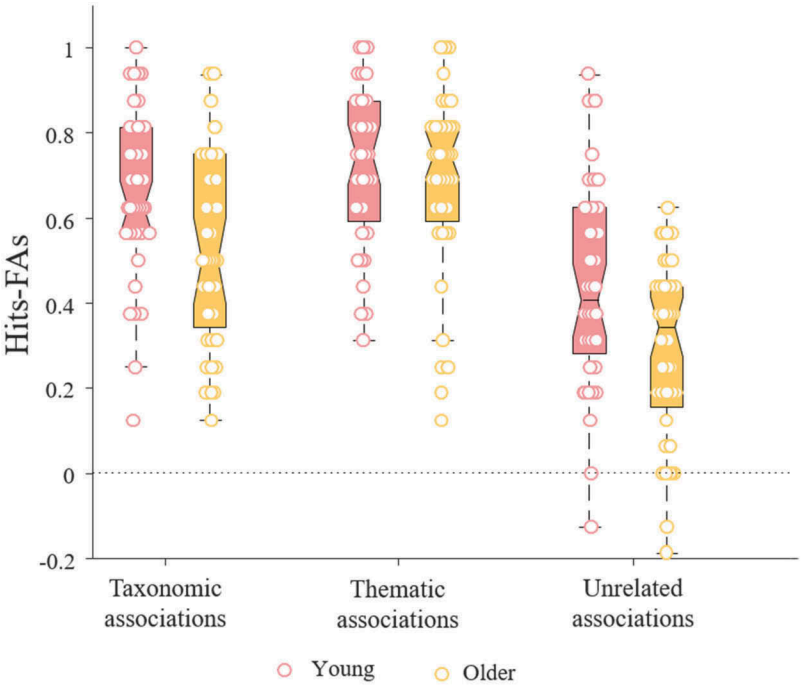

Figure 1. Hits-FAs rate toward recombined pairs across groups and conditions. Each circle is a participant. Error bars represent the minimum and maximum points of the distribution, excluding outliers.

violation (Mauchly's W = .92, p = .046), the repeated measures ANOVA indicated a main effect of type of relationship, F(1.85,136.95) = 109.45, p < .001, η^2_p = .60, with better performance for thematically-related than taxonomically-related pairs (Bonferroni, p < .001) and better performance for taxonomically-related than unrelated pairs (Bonferroni, p < .001). There was also a main effect of group, F(1,74) = 4.82, p < .05, η^2_p = .06. Moreover, the interaction between group and type of relationship was significant, F(1.85,136.95) = 5.19, p < .01 η^2_p = .07. Independent samples t tests indicated that while older adults displayed poorer performance than young adults for unrelated word pairs, t(74) = −2.72, p < .01, Cohen's d = −0.62, 95% CI [−0.25, 0.04], as well as for taxonomically-related word pairs, t(74) = −2.27, p < .05, Cohen's d = −0.52, 95% CI [−0.21, −0.01], there was no group difference for thematically-related pairs, t(74) = 0.20, p = .84, Cohen's d = 0.05, 95% CI [−0.07, 0.09]). We further ran a Bayesian analysis comparing the null and the alternate hypotheses in a model that includes the interaction between type of relatedness and age group, while treating the effects of group and type of relationship as nuisance factors. This time, the alternative model was preferred to the null model by a Bayes factor of 5.39, supporting the idea that age-related associative memory differences are modulated by the type of relationship at encoding.

Finally, after checking for sphericity (Mauchly's W = .96, p = .21), the repeated measure ANOVA on the index of pair recognition performance revealed a main effect of the type of relationship, F(2,156) = 21.15, p < .001, η^2_p = .21, with better performance for thematically- and taxonomically-related than unrelated pairs (Bonferroni, p < .001), but

no performance difference between thematically-related and taxonomically-related pairs (Bonferroni, $p = .30$). There was no main effect of group, $F(1,78) = 0.10$, $p = .75$, $\eta^2_p = .01$, and no interaction between group and type of relationship, $F(2,156) = 0.24$, $p = .78$, $\eta^2_p = .01$.

Discussion

This study aimed at evaluating the impact of the presence as well as the nature of semantic relationships between paired associates on associative recognition memory in young and healthy older adults. We hypothesized that older adults should benefit to a greater extent from prior knowledge within associations in the case of thematic as compared with taxonomic relationships, since those were shown to allow associative recognition to rely only on familiarity, preserved in aging as opposed to recollection. In turn, we expected pairs containing taxonomic relationships to be better recognized than unrelated pairs.

When considering the results at the group level, we found evidence of an associative memory deficit in all conditions. As observed previously, this was mainly due to enhanced false recognition of recombined pairs. Moreover, across both young and older adults groups, thematically-related pairs were better recognized than were taxonomically-related pairs, which were in turn better recognized than unrelated pairs. This suggests that the presence of a semantic relationship and the nature of this relationship (thematic more than taxonomic) have a beneficial effect on associative discrimination. However, with the exception of a smaller effect size of the age effect in the false recognition of recombined thematic pairs, whole-group analyses failed to support the hypothesis that the nature of the semantic relationship may modulate the amplitude of age-related differences. This may be explained by a difficulty of older adults to distinguish experimentally-familiar studied pairs from preexperimentally-familiar semantically-related recombined pairs. Previous studies indeed showed that preexperimental familiarity, not only of the studied pairs but also of the recombined pairs, could modulate the presence or absence of benefit from prior knowledge in associative memory in older adults (Delhaye et al., 2019).

However, results were not homogeneous among the group of older adults and 4 older participants stood out by evidence of outlier performance. When excluding those participants from the analyses, it appeared that, in the presence of thematic relatedness specifically, but not taxonomic relatedness, older adults' associative memory did not differ from that of young adults.

So, for these analyses on 90% of the original sample, the findings are consistent with our main hypothesis according to which thematic relationships are more beneficial to older adults' associative memory than taxonomic relationships, which in turn, are better recognized than unrelated associations, in line with the idea that thematic knowledge organization is preserved longer in the course of aging than is taxonomic knowledge organization (Belacchi & Artuso, 2018). However, because no semantic memory evaluation was conducted in the current study, this interpretation is speculative and should be addressed in future studies.

These results could be understood by considering that thematic relationships allowed for an increased reliance on familiarity (Kriukova et al., 2013), preserved in aging, as opposed to recollection usually necessary for associative recognition but impaired in aging (Koen & Yonelinas, 2014). Here, beyond the notion of increased reliance on familiarity, the idea is

rather that familiarity can be used because it is more reliable for the recognition of thematic pairs. In contrast, recognition of taxonomic pairs, although it involves familiarity to a greater extent than the recognition of unrelated word pairs, also was shown to require the contribution of recollection (Greve et al., 2007; Kriukova et al., 2013).

Moreover, because they are integrative in nature (Estes & Jones, 2009), thematic relationships may increase the reliable use of familiarity during recognition because they foster the use of a unitization strategy at encoding (Badham, Estes, & Maylor, 2012; Kriukova et al., 2013). Unitization is an encoding strategy that allows to encode an association as one single item (Graf & Schacter, 1989), and thereby supports subsequent associative familiarity-based recognition (Yonelinas et al., 2010). Like semantic relatedness, the encoding strategy of unitization has been shown to improve associative memory in aging (Badham et al., 2012; Bastin et al., 2013; D'Angelo et al., 2016) and some authors consider that the benefit of semantic relatedness on the age-related associative deficit is actually due to unitization (Delhaye, Tibon, Gronau, Levy, & Bastin, 2017).

Another possibility to interpret this performance enhancement following thematic relatedness over taxonomic relatedness, which is not exclusive from previous accounts mentioned above, is the idea that thematic relationships bear less similar or overlapping features than taxonomic ones, since categories are by definition organized by the overlap of features amongst concepts, while the different themes thematic associations belong to might make them more distinct. Thus, thematic associations should be more distinctive, or less confusable, than taxonomic ones, which could explain their better discrimination, particularly in older adults.

Altogether, because of the heterogeneity of the findings within the older group, we must be cautious before concluding that the extent to which semantic relatedness can support declining associative memory recognition of older individuals is modulated by the nature of the relationship between the memoranda. It is intriguing that 4 of our older participants were outlier to the distribution of their group, and this was the case for the thematic-relatedness condition only, while their performance was well within the distribution of the group in the two other conditions. This observation was surprising since the thematic-relatedness condition seemed like the one that was best performed by older adults generally. Yet, these 4 participants did not manage to take advantage of the presence of thematic previous knowledge within the to-be-learnt associations. Curiously, these participants did not display any particular characteristics that could explain their performance, at least within the collected data, such as particular old age, particularly low level of education nor weak vocabulary. However, we cannot exclude the possibility that some subtle early changes in their semantic knowledge or semantic processing could explain their pattern of performance.

Note

1. Because Levene's test was significant ($p < .05$), suggesting a violation of the equal variance assumption for the thematic relatedness condition, we also ran non-parametric mean comparison analysis on this measure, which showed comparable results: W = 1071, $p < .01$, rank biserial correlation = .34, CI [0.01, 0.12].

Highlights

- Older adults display a decline in associative memory performance for arbitrary associations
- The age-related associative memory difference disappears for thematically-related associations, but not for taxonomically related ones.
- This pattern was not present in 4 older adults outlier to the distribution, that did not take advantage from thematic relationships in associative memory. The reason for this result still needs to be understood.

Disclosure statement

Emma Delhaye, Adrien Folville and Christine Bastin declare that they have no conflict of interest with respect to the research, authorship, and/or publication of this article.

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